

**Distribution and Abundance of Herring
and other Pelagic Fish off the West
Coast of Vancouver Island in
September, 1981**

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DISTRIBUTION AND ABUNDANCE OF HERRING AND OTHER PELAGIC FISH
OFF THE WEST COAST OF VANCOUVER ISLAND IN SEPTEMBER, 1981

by

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ABSTRACT

Taylor, F. H. C. 1984. Distribution and abundance of herring and other pelagic fish off the west coast of Vancouver Island in September, 1981. Can. Tech. Rep. Fish. Aquat. Sci. 1333: 43 p.

A hydroacoustic and fishing survey was carried out in September, 1981, to determine the distribution and abundance of herring off the west coast of Vancouver Island from the Juan de Fuca Trench to the Ucluth Peninsula. The major herring concentration lay along the outer edge of the continental shelf extending inshore to the Finger Bank and Southeast Corner. There were estimated to be 61,700 t in this region and on Swiftsure Bank. The largest concentration lay between Nitinat and Barkley Canyons. Only about 11% of the herring occurred south of the U.S.-Canada fishing boundary, compared to 46% in September, 1980. No schools of herring were found beyond the edge of the continental shelf.

Hydroacoustic estimates in both September, 1980, and 1981 compared well with estimates derived from catch, spawn and sampling data, considering those stocks spawning on the west coast from Clayoquot Sound south and in the Strait of Georgia south of Nanaimo. In 1980-81, the catch and spawn estimate was 78,666 t, the hydroacoustic estimate 78,220 t; in 1981-82, the estimates were 67,423 t and 61,700 t, respectively.

Factors affecting the reliability of hydroacoustic estimates were discussed. The major causes of bias were considered to be the estimation of target strength and the determination of the species composition of the major fish concentrations.

In September, 1981, 39,600 t of hake, 13,200 t of pollock, 21,800 t of dogfish, 9,870 t of yellowtail rockfish and 8,390 t of redstripe rockfish were located. Corresponding estimates for September, 1980, were 67,230 t of hake, 31,880 t of pollock, 10,120 t of dogfish, 4,645 t of yellowtail rockfish and 3,030 t of redstripe rockfish. Differences in times of migration between the 2 years may explain the biomass differences.

Key words: Hydroacoustic, echointegration, biomass, distribution, Pacific herring, hake, pollock, dogfish, rockfish.

RESUME

Taylor, F. H. C. 1984. Distribution and abundance of herring and other pelagic fish off the west coast of Vancouver Island in September, 1981. Can. Tech. Rep. Fish. Aquat. Sci. 1333: 43 p.

En septembre 1981, on a effectué un levé hydroacoustique et une pêche expérimentale afin de déterminer l'aire de répartition et l'abondance du hareng au large de la côte ouest de l'île Vancouver, à partir de la fosse Juan de Fuca jusqu'à la péninsule d'Ucluth. La plus grande concentration de hareng se trouvait le long du rebord de la plate-forme continentale et se prolongeait vers la côte jusqu'au banc Finger et au Southeast Corner. Dans cette région et sur le banc Swiftsure, le total estimatif s'élevait à 61,700 t, la majorité étant concentrée entre les canyons Nitinat et Barkley. Par rapport à 46%, en septembre 1980, il n'y avait qu'environ 11% du hareng au sud de la limite de pêche canado-américaine. Aucun banc de hareng n'était présent au-delà du rebord de la plate-forme continentale.

Les estimations générées par les données hydroacoustiques recueillies en septembre 1980 et en septembre 1981 se rapprochaient de celles dérivées des données sur les prises, le frai et l'échantillonnage pour les stocks se reproduisant sur la côte ouest, de la baie Clayoquot vers le sud et dans le détroit de Géorgie au sud de Nanaïmo. En 1980-1981, l'estimation des prises et du frai totalisait 78,666 t, par rapport aux 78,220 t déterminées par levé hydroacoustique; en 1981-1982, ces estimations s'élevaient à 67,423 t et à 61,700 t, respectivement.

Le rapport traite des facteurs qui influent sur la fiabilité des estimations par levé hydroacoustique. Les principales sources de distorsion seraient l'estimation de l'index de réflexion des cibles acoustiques et la détermination de la composition par espèce des principales concentrations de poisson.

En septembre 1981, on a localisé 39,600 t de merlu, 13,200 t de morue de Pacifique occidental, 21,800 t d'aiguillat, 9,870 de sébaste à queue jaune et 3,030 t de sébaste à raie rouge. Les estimations correspondantes pour septembre 1980 s'élevaient à 67,230 t, 31,880 t, 10,120 t, 4,654 t et 3,030 t. Les différences entre les saisons migratoires d'une année à l'autre peuvent expliquer les variations de la biomasse.

Mots-clés: hydroacoustique, intégration d'échos, biomasse, répartition, hareng du Pacifique, merlu, morue du Pacifique occidental, aiguillat, sébaste

I. INTRODUCTION

In 1980-1981, three hydroacoustic cruises were conducted off the west coast of Vancouver Island in September, November, and March (Taylor and Kieser 1982). The purpose was to obtain information on the distribution and abundance of herring (Clupea harengus pallasii) and other pelagic species that could be applied to management.

It was found that while estimates of abundance were obtained that agreed reasonably well with the later spawning stock estimates, the timing of the surveys in relation to inshore migration, and so to what stocks or proportions of stocks were present, was important. September may be a little late to ensure that all west coast of Vancouver Island and Strait of Georgia spawners are offshore, while November may be a little early to ensure that only west coast spawners are present. Little information on the distribution and abundance of the pre-recruit year-classes of herring was obtained. Almost no herring of the 1981 year-class and relatively few of the 1980 year-class were found.

The September, 1981, offshore hydroacoustic survey was carried out to obtain information on the annual variation in the distribution and abundance of herring and some other pelagic species. Such information could be of value in timing future surveys. Time was also allotted to searching the area immediately beyond the edge of the continental shelf to determine if there were any indications of herring, and especially of the pre-recruit year-classes, in this region.

In addition to herring the major pelagic species encountered included hake (Merluccius productus), pollock (Theragra chalcogramma), dogfish (Squalus acanthias) and two species of pelagic rockfish, the yellowtail (Sebastes flavidus) and the redstripe (Sebastes proriger).

The G.B. REED carried out the hydroacoustic survey and the fishing beyond the edge of the continental shelf. A chartered trawler was again used to obtain biological samples and to estimate the species composition in various parts of the survey area. The G.B. REED could have carried out this function herself, but at the expense of the size of the area that could be surveyed and the number of tows that could be made. Because of the several species likely to be encountered and the complexity of their distribution, a large number of tows was most desirable. The chartered trawler also tagged herring offshore as opportunity offered. The returns from these taggings will provide valuable information on the spawning stocks present off the west coast.

II. MATERIALS AND METHODS

This cruise was a combined hydroacoustic and fishing survey of the west coast of Vancouver Island primarily for herring. The Canadian government research vessel G.B. REED was responsible for the hydroacoustic survey, and the chartered trawler SUN MAIDEN (Capt. F. Gale, Jr.) for the fishing survey.

A. HYDROACOUSTIC SURVEY

1. Period and time

The vessels departed from Nanaimo on September 8, 1981, and returned on September 25, 1981. Operations on the west coast of Vancouver Island were between 1015 hrs September 9 and 1935 hrs September 25, 1981. The hydroacoustic survey was carried out only between dawn and dusk, from about 0600-0630 hrs to 2000-2030 hrs.

2. Area and track-lines

The survey area extended from the Juan de Fuca Trench in the south to off the Ucluth Peninsula in the north and from the coastal banks to the upper edge of the continental slope (approximately the 200 m contour). In surveying this area the vessel followed a predetermined grid of track-lines (Fig. 1) using a Loran C track-plotter. Because the track-lines were based on Loran C ranges, the spacing between lines decreased seawards and northwards. The track-lines were between 2.5 and 3.6 nautical miles apart in the south and inshore, and about 2.0 nautical miles apart in the north and offshore. In the north-south direction they were divided into sections about 8.5 nautical miles long. Each block of sections usually required a day to complete. In areas where fish were scarce some lines were omitted. On Swiftsure Bank a more closely spaced V-shaped pattern was run. An additional series of lines (the Z-series) was run from north to south along the outer edge of the shelf. In two areas where herring were abundant, surveys were repeated (the A and AN series and the B series of track-lines).

3. Integration equipment and operation

The hydroacoustic system (Fig. 2) and its operation were essentially the same as used off the west coast of Vancouver Island the preceding autumn (Taylor and Kieser 1982). The system was based on a Biosonics 38 kHz sounder and Simrad EK-S dry-paper recorder, an Ecosonics digital echo integrator and a PDP 11/10 computer.

The output of the echo integrator ($\bar{I}_{mn}$) is proportional to the average echo-intensity taken over the m th depth interval and n consecutive transmissions. It is given by the following equation:

$$\bar{I}_{mn} = \bar{TL} + \bar{TS}_{mn} + \bar{VR} + \bar{SL} + \bar{KTVG} + \bar{RG} + \bar{R100} + \bar{\Psi} + 10 \log \frac{CT}{2} + \bar{TS}_{mn} + 10 \log \bar{\rho}_{mn}$$

where the terms on the right in order are: transmit level, voltage response, receiver gain, shell loss on transmit and receive from towed body cover, band width, TVG correction factor, TVG at reference distance, beam factor, depth slice, average target strength and average fish volume density. All the terms are in decibels¹.

A more detailed discussion of these terms is given by Taylor and Kieser (1980 and 1982). As target strength is dependent on species and size, the equation is solved for the relative volume density:

$$10 \log \bar{\rho}_{mn} + \bar{TS}_{mn} = \bar{I}_{mn} - \bar{TL} - \bar{VR} - \bar{RG} - \bar{SL} - \bar{BW} - \bar{KTVG} - \bar{R100} - \bar{\Psi} - 10 \log \frac{CT}{2}$$

where all the quantities on the right-hand side are known, their values are given in Appendix 1.

The integration depth intervals were 5-10, 10-15, 15-20, 20-25 m, then of 25 m to 300 m and of 50 m to 500 m. For each depth interval an integration value $\bar{I}_{mn}$ is stored on digital tape after every 333 pings. This corresponds to a distance of 1 nautical mile at a survey speed of 9 km. A computer program is used to obtain the relative volume and surface densities for each printout for the entire depth range from 25 m to the bottom or a maximum depth of 500 m. The relative surface densities are plotted along the tracklines drawn on a hydrographic chart of the survey area. Contours are then drawn by hand at intervals of powers of ten. An additional threshold contour ($0.3 \cdot 10^{-6}$) was added to safeguard against weak plankton echoes and noise. This surface density chart (Fig. 3) is the basis for estimating the total fish biomass. The catch information is used to obtain species specific estimates (Taylor and Kieser 1982). The target strength per kilogram (TS/kg) is used as it is less dependent on fish size and species than the TS/fish values.

¹A decibel is 10 times the logarithm of an intensity ratio.

B. FISHING SURVEY

1. Equipment and methods

Fishing was done mainly by the chartered trawler SUN MAIDEN and to a lesser extent by the G.B. REED. The SUN MAIDEN used a nylon midwater box trawl, 5 m² aluminum Söberkrüb otter boards, 50 fath (90 m) sweep lines and a Furuno 400 mark II cableless net sounder. The trawl's mesh size tapered from 36 in (91 cm) stretched mesh in the wings and forward sections to 1 1/2 in (3.8 cm) in the codend. The G.B. REED used an Engel 434 midwater trawl, 3 m² Söberkrüb otter boards, 40 fath (72 m) bridles and an Elac cable-type net sounder. Its trawl was constructed with 15 in (41 cm) mesh at the wings and 1 1/2 in (3.8 cm) at the codend. An additional codend liner with 1 in (2.5 cm) mesh was used.

2. Sampling

Standard sampling techniques were used to estimate the catch by species (Barner, Taylor and McCarter 1982). Details of each tow and the catches by species are given in that report.

The main sampling effort was directed mainly towards herring. Duplicate samples of over 100 fish each were frozen. Age, length, and sex composition were determined in the laboratory. The length frequencies by sex were recorded for the remaining species.

The common names proposed by Hart (1973) are used throughout this report.

III. RESULTS

A. CATCH COMPOSITION

Midwater trawl tows were made to identify the species responsible for the concentrations encountered during the hydroacoustic survey, to estimate species composition in different parts of the survey area, and to provide basic biological information on the major species caught. For these purposes the SUN MAIDEN made 50 tows in the survey area. The tows were not evenly or randomly distributed throughout the area but were concentrated where large bodies of fish were present. More effort was allotted to herring concentrations than to hake and pollock, or rockfish concentrations. The

G.B. REED made 5 additional tows in water beyond the edge of the continental shelf. More tows would have been made had suitable targets been located. The purpose of these tows was to determine if herring concentrations occurred beyond the edge of the shelf.

The locations of the tows made by both vessels are shown on Fig. 4. The tows have been grouped by major concentration. The total catch, catch rate and percentage species composition by weight of each tow are shown in Table 1. The average percentage species composition for each concentration has been calculated using those tows where total catch exceeds 50 kg² (Table 2).

Herring predominated in most of the tows made along the outer edge of the shelf from Loudoun Canyon to Nitinat Canyon, on the Finger Bank and Southeast Corner, and on Swiftsure Bank. In the Loudoun Canyon area catches, and catch rates were low, and contained small numbers of yellowtail and redstripe rockfish. Catch rates were highest in the central section, off Barkley Canyon, the Finger Bank and the Southeast Corner, and on Swiftsure Bank. Off Barkley Canyon, while herring were predominant in about 60% of the tows. The remainder was dominated by dogfish, with catch rates of that almost reached 10,000 kg/hr. In the Finger Bank area dogfish were not as numerous, although in some tows they formed a substantial proportion of the catch. South of the Nitinat Canyon and along the outer part of the Juan de Fuca Trench, yellowtail and redstripe rockfish were the predominant species. In 3 tows lying close to the 200-m contour yellowtail rockfish predominated, while in 3 tows from the rough-bottomed area just to the east, redstripe rockfish were dominant. In Barkley Basin and along the steep inner edge of the Prairie Grounds, hake and pollock were the predominant species. There were small amounts of dogfish in these areas, and on the edge of the Prairies some yellowtail rockfish, and in 2 tows, redstripe rockfish.

B. HERRING AGE COMPOSITION

Herring age was determined from fish length and scales. The age is expressed as an integer, each completed and stated year counts fully. Thus, an age 1 herring is in its first year of life. A herring born in March 1981 is an age 1 herring through April 1982, it belongs to the 1981 year class. In September it shows no winter rings on its scales.

There was little consistency in the age composition among the samples taken from any of the major herring concentrations (Table 3). This suggests that the age composition of the individual schools is quite variable, thus the average age composition of a concentration probably has little meaning. In the concentrations (He 3 & 3A) along the outer edge of the continental shelf from Barkley Canyon south, herring of ages 3 and 4 were each dominant in 3 of the 9 samples, and herring of ages 5 and 7 each in 1 sample, while herring of ages 3, 4, and 5 were equally represented in 1 sample. North of Barkley Canyon more age 2 fish were present than elsewhere. They were

²Tow 7 was omitted, 99% of the catch was one thresher shark.

predominant -- or equally dominant -- in 2 samples, while age 3 fish were dominant in the other 3 samples. A few age 1 fish were also present in 1 sample, the only occasion on which this year-class was sampled. On the Finger Bank and Southeast Corner the age composition was as variable. Herring of ages 3 and 5 dominated in 1 sample each, and fish of age 4 in the remaining 3 samples. On Swiftsure Bank there was a greater proportion of age 3 fish, although age 4 fish were almost as numerous, and age 5 fish dominated in 1 sample. There were also more 2-year-olds present.

C. FISH DENSITY

All the variables in the sonar equation except two are physical parameters, for which values can be obtained by calculation or calibration. There are two biologically based parameters, the desired parameter, fish density, and fish target strength. Since the latter depends on the type and size of fish it is corrected for later in the calculations when the species composition of the various fish concentrations has been determined. The sonar equation is therefore solved for the product of fish density and target strength per kilogram. It is this product that is mapped and contoured. Fish density is expressed as numbers per m^2 of surface area, i.e., the product of $no./m^3$ and average depth. The density-target strength values can be regarded as proportional to biomass. These values are expressed in scientific notation, e.g., $0.156E - 3 = 0.156 \times 10^{-3} = 0.000156$.

On this cruise the exponent varied from -3 to -8. Measurable quantities of fish were considered to be present down to density target strength values of 0.4×10^{-6} (Fig. 5A-D, 6A-C, and 7A-C). At lower values the echograms showed no recognizable fish signs and were increasingly due to plankton and systems noise (Fig. 5E, 6D and 7E).

In herring concentrations the densities ranged from 0.4×10^{-6} to 0.4×10^{-3} , (Fig. 5A-D) i.e. a thousand times. Densities with an exponent of -4 (Fig. 5B) characterized the centres of major concentrations. Occasionally high values with an exponent of -3 (Fig. 5A) occurred in such centres. Lighter concentrations with an exponent of -5 were spread over a more extensive area, linking major concentrations. In typical hake concentrations density values ranged up a hundredfold from values of 0.4×10^{-6} (Fig. 6A-C). Hake typically appeared as a wavy layer in midwater (Fig. 6A-C). Centres of concentration were again marked by values with an exponent of -4 (Fig. 6A); they were more extensive than similar concentrations of herring. Rockfish concentrations marked by values with an exponent of -4 (Fig. 7A and B) were small and scattered. However schools of rockfish (Fig. 7C and D) occurred over the wide intervening areas.

D. TAGGING AND TAG RECOVERIES

Herring were tagged offshore again in 1981. The SUN MAIDEN tagged a total of 11,125 herring from 12 tows as follows: 2,750 tags from 4 tows in the Swiftsure Bank area; 3,102 tags from 2 tows on the Southeast Corner of La Perouse Bank; 1,673 tags from 2 tows off the Nitinat Canyon; 2,050 tags from 2 tows off Barkley Canyon; 500 tags from 1 tow off Loudoun Canyon and 1,050 tags from 1 tow on the Prairie Grounds just south of the U.S.-Canada fishing boundary (Barner, Taylor and McCarter 1982).

This and other tagging experiments lead to recoveries in seine and gill net fisheries in 1980-81 (Haegele, Turner, Hopwo and Miller 1982) and in 1981-82 (Haegele, Hopwo and Turner 1982). A total of 59 tags have been recovered from the offshore taggings; there were 49 whose area of recovery was known. The recoveries are shown by area in the tabulation below:

Recovery Area	Strait of Georgia			West Coast Van. Is		Unknown	Total
	14	17	19	23	24		
No. tags	3	16	1	18	5	6	59

E. FISH DISTRIBUTION AND BIOMASS

1. Herring

In September, 1981, approximately 61,700 t of herring³ were encountered off the west coast of Vancouver Island from the Juan de Fuca Trench north to the Ucluth Peninsula (Table 4). Most of the herring (34,400 t of 56%) were found along the outer edge of the continental shelf. In this region they were most abundant from Nitinat to Barkley Canyons (24,200 t), with 5,100 t (8%) occurring south of the U.S.-Canadian fishing boundary. From Barkley Canyon to Loudoun Canyon, an approximately equal distance, herring were somewhat less abundant, although 10,200 t were found in the concentration off Barkley Canyon. This concentration extended shorewards to the Finger Bank and the Southeast Corner of the La Perouse Bank.

³Biomass is expressed in metric tons. 1 t = 1000 kg = 2205 lbs.

On the edges of the coastal banks another 25,900 t (42% of the total) were located. Of this, there were 16,900 t on Swiftsure Bank, 7,600 t on the Finger Bank and Southeast Corner, and 1,200 t in the area of the Southwest Corner. A small amount of herring (1,384 t or 2% of the total) occurred in the hake and pollock concentrations.

The distribution of herring in September, 1981, was intermediate between the September and November, 1980, distributions (Taylor and Kieser 1982) and suggests that the prespawning migration was more advanced in September, 1981, than in September, 1980. Along the outer edge of the shelf there was less herring south of the U.S./Canada fishing boundary and more inshore in the Finger Bank area. The concentration on Swiftsure Bank was also larger.

The total amount of herring off the southern part of the west coast of Vancouver Island (61,700 t) was about the same as in September, 1980 (67,740 t, of which 5,630 t was north of the 1981 survey area). The major difference between the two years lay in the distribution, with a much smaller proportion (11% in all) occurring south of the U.S./Canada fishing boundary.

2. Other fish

In September, 1981, 39,600 t of hake, 13,200 t of pollock, 21,800 t of dogfish, 9,870 t of yellowtail rockfish and 8,390 t of redstripe rockfish were located (Table 3). The hake and pollock occurred shorewards of the major herring concentration, in the Barkley and Cape Beale Basins, along the steep eastern edge of the Prairie Grounds and in the Juan de Fuca Trench. The amount of hake was only 58% of that in the previous September but about 17% more than in November, 1980 (33,870 t). This again suggests that the season was earlier and more of the hake may have migrated south by September in 1981 than in 1980. Pollock were much less numerous than in either September (31,880 t) or November (25,090 t) 1980.

Dogfish were more numerous than in September, 1980 (10,120 t) but less so than in November of that year (33,453 t). Most of the dogfish were mixed with the herring concentrations along the outer edge of the continental shelf. In this, they resembled their distribution in November, 1980, more than September, 1980.

The amount of yellowtail rockfish was again intermediate between the September (4,645 t) and November (14,435 t) 1980 biomasses and was again concentrated on the outer edge of the shelf from the Nitinat Canyon to the Juan de Fuca Trench. Redstripe rockfish appeared to be much more numerous than in either September or November, 1980 (3,755 t and 3,030 t respectively). The quantity along the outer edge of the shelf from Barkley Canyon north was about the same in the two years; the difference was due to the quantity located in 1981 on the southern Prairie Grounds.

3. Repeated surveys

In September, 1980, some information was obtained that showed that surveys on consecutive days produced reasonably similar biomass estimates, although stock movement over a period of days would affect the estimates

(Taylor and Kieser 1982). Further information on stock movement and its affect on biomass was sought during the September, 1981, survey. It was planned to survey an area on at least 2 consecutive days and the intervening night. An area (Fig. 8) along the outer edge of the shelf where herring were abundant was selected. As the survey of this area required almost 13 hours, the entire night survey could not be completed. Rapidly deteriorating weather first slowed down and then forced termination of the second day's survey in midmorning. There was insufficient time remaining when the weather again moderated to repeat the survey. The remaining day available was used to resurvey a more inshore area covering the Southeast Corner of La Perouse Bank, the Finger Bank and south to the U.S./Canadian fishing boundary. The southern part of this area overlapped the eastern part of the first area.

Thus no additional information was obtainable on the repeatability of daily estimates. The most that could be obtained was some information on the change in distribution and biomass with time. Even this information was not precise since, because of the arrangement of the daily survey blocks of transects, the original survey of the selected area occurred over parts of 3 days.

The distribution and biomass in 3 parts of the total repeat survey area can be compared with those obtained on the original survey (Table 5). The parts of the area are the Southeast Corner-Finger Bank region (Fig. 8, north of the dotted diagonal), the outer edge region (Fig. 8, south of the dotted diagonal to the dashed U.S./Canadian fishery boundary), and the region south of the boundary. The Southeast Corner-Finger Bank region was originally surveyed between September 12th and 15th; the repeat survey was on September 22nd. In the intervening 7 to 10 days the estimated herring biomass increased almost fourfold from about 9,400 t to 36,300 t. The outer edge area, south of the diagonal to the U.S./Canadian border was originally surveyed between September 13th and 15th, and was resurveyed on September 19th. The intervening period of 4-6 days was shorter than in the more northern area. In this period the estimated herring biomass decreased by almost a half, from about 29,800 t to 15,200 t. The area south of the fishing boundary was originally surveyed on September 17th and was resurveyed on September 19th. In the intervening 2 days the estimated biomass increased from about 6,100 t to 9,700 t. The total amount of herring in the resurveyed areas increased from about 45,400 t to 61,300 t in the 2- to 10-day interval.

On the outer edge of the shelf north of the Nitinat Canyon there appears to have occurred a pronounced eastward movement of herring to the area south of the Finger Bank. The herring apparently then spread north over the Southeast Corner of La Perouse Bank. The increase in the total amount of herring in the surveyed area suggests that there must have been a movement of herring into the Nitinat Canyon area, probably from the north.

4. Comparison of hydracoustic and other estimates

As has been pointed out in an earlier section, the herring biomass estimate of 61,700 t was about the same as the September, 1980, estimate when adjustments are made for the quantities north of Amphitrite Point and off Victoria.

A September offshore estimate is difficult to compare to any of the spawning stock estimates. The offshore stock in September off southern Vancouver Island will consist of some or all of the west coast spawning stocks plus some portion of the Strait of Georgia stocks.

In September, 1980 and 1981, herring were tagged offshore off southern Vancouver Island. In 1980-81 recoveries were too few to provide much meaningful information about the stocks involved. However, by 1981-82 sufficient tags had been recovered to provide some information, although the number of recoveries was still small. Based on the total number of recoveries certain as to recovery area (49) in both seasons from both the 1980 and 1981 taggings (Table 5), 46% were recovered from Barkley and Clayoquot Sounds (Areas 23 and 24), 35% from the Strait of Georgia south of Nanaimo (Areas 17 to 19), 12% from Nootka Sound and Nuchatlitz Inlet (Area 25) and 6% from the Strait of Georgia north of Nanaimo to Comox (Areas 13 to 16). Taylor (1964) suggests that the herring in the northern part of the Strait of Georgia may enter from the north via Johnstone Strait. They would thus not be present off the southern west coast of Vancouver Island. The above tag recoveries, although relatively few in number, tend to support the contention that Strait of Georgia herring summering off the west coast may be from the southern part of the Strait.

The 1980 and 1981 September hydroacoustic biomass estimates can be compared to the biomass estimates (Stocker, Haist and Fournier 1982) derived from catch, spawn and sampling data using Hourston's method (Hourston 1981). On the west coast all stocks from Barkley Sound (Areas 23) to Nuchatlitz Inlet (Area 25) are included, and, in the Strait of Georgia only those stocks south of Nanaimo. The results are shown in the following tabulation, which also includes the hydroacoustic estimates.

Biomass of herring (metric tons)						
From catch, spawn and sampling data						
Year	Barkley and Clayoquot Sounds	Nootka Sound	Nuchatlitz Inlet	St of Georgia S of Nanaimo	Total	Hydroacoustic Estimate
1980-81	41,532	4,991	10,589	21,554	78,666	78,220
1981-82	15,317	6,413	10,910	34,910	67,423	61,700

There is surprisingly good agreement in both 1980 and 1981 between the hydroacoustic biomass estimates and those derived from catch, spawn and sampling data. Estimates from this source include all stocks in Nootka Sound and Nuchatlitz Inlet (Areas 25). About 12% of the recoveries from tags released offshore the west coast were made in Areas 25, compared to about 46% in Areas 23 and 24. However, there is no way at present of estimating the proportion of Area 25 spawning stocks to be found to the south. The inclusion of all Area 25 fish may lead to an overestimate of the total biomass. On the other hand the Strait of Georgia catch and spawn estimates may be too small. These estimates include only herring found south of Nanaimo. A small proportion (about 6%) of the tags recovered were returned from north of

Nanaimo. Thus some fish spawning north of Nanaimo may occur off the west coast. However, once again the proportion of those stocks that summer off the west coast cannot be determined. The hydroacoustic estimate in 1980 contains 10,480 t from the Victoria area. No estimate was made in this area in 1981.

The hydroacoustic estimate cannot at present be compared to surplus production model estimates (Stocker, Haist, and Fournier 1982) since these have been calculated only for major areas, the entire west coast of Vancouver Island or the whole of the Strait of Georgia and Johnstone Strait.

5. Reliability of hydroacoustic biomass estimates

The accuracy and precision of hydroacoustic estimates will depend on the variance of the density estimates and on bias arising from several sources. No adequate method has been uncovered to estimate the relative variance of a variable sampled sequentially along a predetermined grid of track-lines. Shotton and Dowd (1975) discuss some possible approaches. These include the usual method based on the assumption of normal distribution (Forbes and Nakken 1972), autocorrelation (Bayley and Hammersley 1948), and cluster analysis (Hansen, Hurwitz and Madow 1953). Since the variance estimates from the latter two methods do not differ appreciably from the first (Taylor and Kieser 1982), the relative variance derived by the first method may provide some indication of the size of the variance. Considering only those concentrations with more than 20 density estimates, in 5 herring concentrations the relative standard deviation was 12 to 48%, in 3 hake concentrations 16 or 17%, and in one 40%, and in 3 rockfish concentrations 17-21%. Herring densities were more variable than those for hake or rockfish.

Bias arises from several major sources of error. These include:

1. Conversion of acoustic signal information to a biomass estimate. The main components are:
 - a) Calibration and stability of the echo integration system.
 - b) Estimation of in situ target strength.
2. Determination of species composition -- or failure to discriminate between schools of different species.
3. Visibility to the system of all fish concentrations within the operating range.
 - a) Fish too close to the surface or the bottom.
 - b) Behavior of schools in response to the passage of the vessel, vessel avoidance.
4. Proportion of the total stock within the survey area.
5. Movement of schools in relation to the survey grid.

Fiedler (1978), in addition to these factors, lists 4 others which are of importance in surveys involving echo ranging (horizontal searching) but are not of major importance in echo sounding (vertical searching). These are:

1. The affect of varying hydrographic conditions on the acoustic signal. Changes in water temperature and salinity by effecting sound velocity can bend the beam upwards of downwards.
2. Unschooled fish and small schools are not detected. At the gain settings used and over the range of depths encountered small schools and even single fish are readily detectable during echo integration surveys.
3. Blocking of signals to and from fish far from the ship by fish nearer at hand. This does not appear to be a problem in echo integration surveys, although on occasions when extremely dense schools were encountered, some reverberation or scattering of the signal has been noticed.
4. Inability to survey in shallow water. This is certainly not a problem offshore. In echo sounder surveys the minimum depth will be determined by the depth of the transducer and the suppression distances required to protect the receiver from transmission pulses (usually 5 m). In shallow water, other effects such as vessel avoidance could become of greater significance.

• Taylor and Kieser (1982) discuss the effects of the major sources of error, although the sixth source below is not explicitly considered in detail.

1. Calibration is at the state-of-the-art level and is considered accurate to within ± 0.5 dB. All components of the system have proved stable over several years of use.
2. The bias introduced by using average TS values calculated from a formula derived from TS values given in the literature (Appendix 1) may be less than originally considered (± 1 dB). Edwards (1980) obtained target strength values for herring from aged fish experiments which correspond to that used. He showed that the effect of changes in depth were unexpectedly small in herring in comparison to those in fish with closed air bladders.
3. Neither vessel avoidance nor occurrence near the surface appear major problems in offshore surveys. Schools usually lie closer to the bottom than to the surface in water 50 to 100 m deep. Some small schools may lie below the bottom tracking buffer and so effectively avoid integration.
4. Migration of herring and hake out of the survey area may have occurred during the course of the survey -- herring into the Strait of Georgia, hake southwards. It is thus difficult to know what proportion of the total stock of these species is within the survey area at the time of the survey.
5. The determination of species composition perhaps still remains the major source of error. It depends on the results of test fishing, although species identification from echo sounder records at times yields additional information.

6. The movement of the schools in relation to the survey grid was not considered in detail in previous reports. The repeat surveys discussed in a previous section showed the main centre of herring abundance shifted 8-10 nautical miles in a 4- to 10-day period. These surveys provided no real information on whether such movement would bias the total biomass estimate for the cruise. The surveys were carried out on blocks of transects 8 to 9 nautical miles long, parallel to the coast. The legs were 2 to 2-1/2 nautical miles apart. The survey speed was such that opposing points on adjacent legs were less than 1/2 to 2 hours apart. The easterly movement of the main herring concentration seemed to occur in one block of legs (the F series) running 8-9 nautical miles north from the U.S./Canadian fishing boundary. This block was surveyed in the direction that opposed the movement. In spite of this, the average speed of migration of at the most 2 nautical miles per day does not appear such that in a 2-hr period there was an appreciable likelihood of the same herring being surveyed twice on adjacent legs. On the outer edge of the shelf, the survey proceeded from north to south, with adjacent blocks usually surveyed on consecutive days. In one instance, near the centre of the concentration along the outer edge of the shelf, adjacent blocks were surveyed the same day. The concentration south of the U.S./Canadian border was also surveyed on consecutive days, although 2 days after the block immediately to the north. If the speed of the apparent southward movement is the same as the eastward movement, there is perhaps some opportunity for fish that were in the southern quarter of one block of transects to be seen again in the northern quarter of the next block. The possibility remains that the movement of herring with relation to the survey grid, in spite of the mitigating factors mentioned, may constitute a source of error. It cannot be properly assessed from the present surveys.

IV. SUMMARY

1. The hydroacoustic survey from September 8-25, 1981, extended from the Juan de Fuca Trench north to the Ucluth Peninsula. A fishing survey was carried out at the same time by the chartered trawler SUN MAIDEN.
2. The SUN MAIDEN made 50 midwater trawl tows usually of 30 min duration.
 - a) Most of the tows were in the major herring concentrations along the outer edge of the continental shelf. Catches of herring varied from 6 to 13,684 kg in tows of 11 to 60 min. About one half as many tows were made on the inshore banks (the Southeast Corner, Finger Bank, and Swiftsure Bank). Catches varied from 66 kg to 13,504 kg in tows of 6 to 40 min.
 - b) There were 10 tows made in the main hake and pollock concentrations. Catches of hake varied from 75 kg to 2,783 kg and of pollock from 37 to 1,663 kg. Tow length varied from 11 to 35 min.

- c) The largest catch of dogfish was 5,736 kg in a 38/min tow made in the major offshore herring concentration. This species occurred in a measurable quantity in 8 out of the 23 tows in this area. Inshore dogfish catches were generally smaller, from 27 to 668 kg with one catch of 3,709 kg. They occurred in 9 out of 13 tows.
 - d) Yellowtail rockfish catches varied from a trace to 1,903 kg, and occurred in 25 of the 50 tows made. Redstripe rockfish catches varied from a trace to 445 kg and occurred in 16 of the 50 tows.
3. The SUN MAIDEN tagged a total of 11,125 herring from 4 tows on Swiftsure Bank, 2 tows on the Southeast Corner, 2 tows off the Nitinat Canyon, 2 tows off Barkley Canyon, 1 tow off Loudoun Canyon and 1 tow on the Prairie Grounds just south of the U.S./Canadian fishing boundary.
4. Herring were predominately 3 and 4, and to a lesser extent, 5 years old. There was not any noticeable consistency among samples from tows in any one concentration, suggesting that the age composition of individual schools may vary. There was perhaps more young herring (ages 1 and 2) along the outer edge of the shelf north of Barkley Canyon than elsewhere.
5. Herring biomass. In September, 1981, there were estimated to be 61,700 t of herring from the Juan de Fuca Trench north to the Ucluth Peninsula. Most of the herring (34,400 t) were along the outer edge of the continental shelf, with only 5,100 t south of the U.S./Canadian fishing boundary. Another 25,900 t were located on the coastal banks. Of this, 16,900 t were on Swiftsure Bank.
6. Hake and pollock biomass. In September, 1981, there were estimated to be 39,600 t of hake and 13,200 t of pollock. They occurred in Barkley and Cape Beale Basins and along the steep eastern edge of the Prairie Grounds. The amount of hake was only 58% of that observed the previous September and about 12% more than in November, 1980. Pollock were much less numerous than in either September (31,880 t) or November (25,090 t), 1980.
7. Dogfish biomass. Dogfish biomass amounted to 21,800 t, more than in September (10,120 t) but less than in November, 1980 (33,455 t). Most were mixed with the herring concentrations along the outer edge of the continental shelf.
8. Rockfish biomass. The amount of yellowtail rockfish (9,870 t) was intermediate between the September (4,655 t) and November, 1980 (14,435 t) amounts. Redstripe rockfish (8,389 t) appeared more numerous than in either September or November, 1980 (3,755 t and 3,030 t, respectively).
9. The repeated survey test was terminated by bad weather after the first day. The test did no more than show that a considerable body of herring had moved inshore and northwards in the interval between the original survey and the repeat survey.

10. The herring biomass estimates in September, 1980, and 1981, were shown to agree surprisingly well with estimates based on catch, spawn, and sampling data provided only herring spawning in the southern part of the Strait of Georgia were considered in addition to the west coast herring. The estimates in 1980-81 were 78,666 t (catch and spawn) and 78,220 t (hydroacoustic) and in 1981-82, 67,423 t and 61,700 t, respectively.

11. Reliability of estimates. The various factors affecting the reliability of the estimates were discussed. The major factors are probably the target strength values, and the determination of the species composition of the various concentrations. Other less important factors are visibility to the system of all fish concentrations within the operating range, the proportion of the total stock within the survey area, movement of schools in relation to the survey grid, and finally the calibration and stability of the echo integration system. No suitable model has been found for estimating the variance of the density estimates. The simplest method available gave relative standard deviations for large herring concentrations of 12 to 45%, for hake concentrations of 16 to 40%, and for rockfish concentrations 17 to 21%. Relative variance depended on the number of density observations and particularly upon their range.

V. CONCLUSIONS

1. It seems probable that herring in quantity do not occur beyond the outer edge of the continental shelf. No evidence of herring schools was found in several days additional searching and fishing by the G.B. REED over the continental slope. No concentrations of pelagic fish were located. Catches from the few tows attempted were small, all under 200 kg, and 3 out of the 5 under 100 kg. The catches were predominantly hake and dogfish.

2. There appears to be considerable annual variation in the movement of herring and other pelagic species offshore. This variation changes the proportion of the stocks likely to be found north and south of the U.S./Canadian fishing boundary. Between 1980 and 1981 there was perhaps as much as 2 to 4 weeks variation. In comparison to 1980 relatively few herring were found in September, 1981, south of the U.S./Canadian fishing boundary. On the other hand more were found farther inshore in the Southeast Corner-Finger Bank area. Considerably less hake was found in Canadian waters in September, 1981, than in September, 1980. Dogfish seemed to have appeared and moved inshore earlier in 1981 than in 1980.

3. The recovered tags from the 1980 and 1981 offshore tagging suggest that most west coast herring spawn in Barkley and Clayoquot Sounds (46%), and in the southern Strait of Georgia south of Nanaimo (35%). Only 6% were recovered north of Nanaimo, and on the west coast, only 12% north of Esteban Point in Nootka Sound and Nuchatlitz Inlet.

4. Hydroacoustic biomass estimates appear quite as reliable as estimates by other available methods. They have the advantage of speed and a lead time of 4-6 months before the major seine and gillnet roe fisheries. Surprisingly good agreement was found in both 1980-81 and 1981-82 between the hydroacoustic biomass estimates in September and those derived from catch, spawn, and sampling data, provided only herring spawning on the west coast and in the Strait of Georgia spawning south of Nanaimo were considered, rather than all Strait of Georgia stocks. The comparable catch and spawn and hydroacoustic estimates are 78,666 t and 78,220 t, respectively, in 1980-81 and 67,423 and 61,200 t, respectively, in 1981-82. The hydroacoustic estimates at present cannot be compared to surplus production model estimates since the latter have been calculated only for wide major areas.

5. The major sources of bias were again considered to be the target strength value used for each species and the species composition of the major concentrations. The movement of herring with respect to the survey grid was discussed in some detail. It was concluded it was not a major source of error, although in some circumstances it might affect estimates made on succeeding days.

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Table 1. Total catch (kg), catch rate (kg/hr) and percentage species composition by tow for major fish concentrations on the West Coast Vancouver Island, September 8-25, 1981.

Fish concentration	Locality	Tow number		Duration	Total catch (kg)	Catch rate (kg/hr)	Percentage								
							Herring	Eulachon	Hake	Pollock	Dogfish	Yellowtail rockfish	Redstripe rockfish	Other rockfish	Other
He2	Loudoun Canyon	12	15	20	80	5	5	-	-	-	24	-	-	66	
		14	31	39	75	10	-	-	-	-	5	-	85	-	
		15	36	59	98	7	39	-	-	-	3	1	49	-	
		16	20	196	588	77	-	-	-	-	1	22	-	-	
		17	60	682	682	69	-	-	-	-	-	29	2	+	
		19	37	283	459	90	-	+	-	+	-	1	-	8	
		45	42	130	186	61	-	-	-	-	34	-	-	5	
		13	34	201	355	91	-	-	-	-	-	-	5	4	
average					77	-	+	-	+	7	11	1	4		
He3	Barkley Canyon	18	46	6	8	100	-	-	-	-	-	-	-	-	
		20	44	1,065	1,452	71	-	1	-	8	-	19	+	1	
		21	30	31	62	3	-	-	-	-	10	45	10	32	
		22	11	13,684	74,650	100	+	-	-	-	-	+	+	-	
		23	14	1,935	8,293	5	-	-	-	93	-	-	1	+	
		24	40	1,864	2,796	49	-	-	-	49	-	-	2	-	
		7	40	137	206	1	-	-	-	-	-	-	-	99	
		8	30	909	1,818	100	-	-	-	-	-	-	-	-	
		9	41	404	591	-	-	-	-	97	-	3	-	+	
		29	30	71	142	87	-	-	-	-	3	6	-	5	
		30	38	5,934	9,369	+	-	-	-	97	2	1	-	+	
		43	27	2,273	5,051	45	-	-	-	55	-	-	-	-	
		average					51	+	+	-	44	1	3	+	1
He3A	South of Nitinat Canyon	34	38	3,182	5,024	92	-	-	-	3	-	5	+	-	
		R5*	50	143	172	52	-	15	-	31	-	-	1	-	
		35	24	16	40	78	-	-	-	-	-	-	-	22	
average					72	-	8	-	17	-	2	1	-		
He10	Swiftsure Bank	1	15	3,681	14,724	99	-	-	-	1	-	-	-	-	
		2	6	2,755	27,550	99	-	-	-	1	-	-	-	-	
		48	14	1,818	7,791	86	-	-	-	14	-	-	-	+	
		49	40	13,640	20,460	99	-	-	-	1	-	-	-	+	
		50	33	549	998	83	-	-	-	17	1	-	-	-	
		47	25	183	439	36	-	-	-	52	2	-	-	10	
average					84	-	-	-	14	+	-	-	2		

Table 1 (cont'd).

Fish concentration	Locality	Tow number	Duration	Total catch (kg)	Catch rate (kg/hr)	Percentage								
						Herring	Eulachon	Hake	Pollock	Dogfish	Yellowtail rockfish	Redstripe rockfish	Other rockfish	Other
He4	Finger Bank	3	30	645	1,090	87	-	-	-	9	+	-	-	3
		5	26	2,736	6,314	100	-	-	-	-	-	-	-	+
		40	16	1,629	6,109	56	+	-	-	41	+	-	-	3
		26	13	8,183	37,768	99	-	-	-	-	-	-	-	+
		42	21	15,455	44,157	76	-	-	-	24	-	-	-	-
		44	30	3,729	7,458	98	-	-	-	2	+	-	-	-
average						86	-	-	-	13	+	-	-	1
Hal4	Prairies	6	30	3,636	7,272	-	-	57	39	4	-	-	-	+
		25	30	630	1,260	-	-	25	-	-	51	12	11	+
		28	15	1,268	5,072	-	+	53	39	1	8	-	-	-
		31	18	529	1,763	-	-	79	19	2	-	-	-	+
		41	34	116	205	-	-	62	32	2	4	-	-	-
		46	35	2,514	4,310	-	-	72	2	-	20	-	-	7
average		4	30	2,727	5,454	+	-	15	61	1	4	20	-	+
average						+	+	52	27	1	12	5	2	1
Hal3	Barkley Basin	10	32	655	1,228	+	+	76	14	9	+	-	-	1
		11	15	3,162	12,648	-	-	88	10	1	-	-	-	1
		27	11	1,336	7,287	-	-	72	26	2	-	-	-	1
average						+	+	79	17	4	+	1	1	1
Ro1	South Prairies	32	42	52	74	42	-	-	-	-	5	52	1	-
		83	60	6	6	8	-	-	-	-	31	62	-	-
		36	27	887	1,971	10	-	-	-	-	90	-	+	-
		37	30	10	20	-	-	-	-	-	100	-	-	+
		38	40	2,266	3,399	-	-	-	-	-	84	14	2	-
		39	20	454	1,362	-	-	-	-	-	+	98	2	-
average						13	-	-	-	-	45	41	1	-
		R1*	30	198	396	+	-	-	-	100	-	-	-	+
		R2*	43	66	92	-	-	3	-	97	-	-	-	-
		R3*	50	25	30	-	-	96	-	4	-	-	-	-
		R4*	39	51	77	-	-	47	22	-	-	-	30	+

*Tows R1 to R4 were made by the G.B. REED, the other tows were made by the SUN MAIDEN.

Table 2. Percentage species composition of the major fish concentrations encountered off the West Coast of Vancouver Island, September 8-25, 1981.

Location	Conc. no.	No. of tows ¹ included	Percentage								
			Herring	Eulachon	Hake	Pollock	Dogfish	Yellowtail rockfish	Redstripe rockfish	Other rockfish	Other
Loudoun Canyon	He 2	5	77.4	-	0.1	-	0.1	7.0	10.5	1.4	3.6
Barkley Canyon	He 3	9	50.7	-	0.1	-	44.3	0.5	3.1	0.5	0.8
South of Nitinat Canyon	He 3A	2	72.3	-	7.6	-	16.8	2.4	0.7	-	-
Southeast Corner - Finger Bank	He 4	6	86.1	-	-	-	12.7	0.1	-	-	1.1
Swiftsure Bank	He 10	5	93.1	-	-	-	6.7	0.2	-	-	0.1
Barkley Basin	Ha 13	3	+	0.1	78.7	16.6	3.8	+	-	-	0.9
Prairies	Ha 14	7	+	0.1	51.6	27.3	1.3	12.4	4.6	1.6	1.2
South Prairies	Ro 17	4	13.0	-	-	-	-	44.9	41.0	1.1	-

¹Tows containing less than 50 kg or which consisted predominantly of a single large fish were omitted.

Table 3. Herring percentage age composition by sample and fish concentration, West Coast of Vancouver Island, September 8-25, 1981.

		Age (in year of life)										
Location		Haul number	1	2	3	4	5	6	7	8	9	10+
Loudoun Canyon	He 2	13	2.4	84.1	13.4	-	-	-	-	-	-	-
		16	-	-	59.4	24.6	8.7	5.8	1.4	-	-	-
		17	-	8.6	57.1	17.1	14.3	1.4	-	-	1.4	-
		19	-	41.9	41.9	13.5	1.4	1.4	-	-	-	-
		average	0.60	33.65	42.95	13.80	6.10	2.15	0.35	-	0.35	-
Barkley Canyon	He 3	8	-	-	40.2	26.8	13.4	11.0	7.3	1.2	-	-
		20	-	-	38.0	41.8	10.1	6.3	2.5	-	1.3	-
		22	-	-	3.6	9.6	41.0	24.1	9.6	8.4	2.4	1.2
		23	-	-	24.2	24.2	22.7	9.1	10.6	6.1	1.5	1.5
		24	-	-	13.7	35.6	30.1	15.1	2.7	1.4	1.4	-
		29	-	3.9	50.0	17.1	13.1	7.9	5.3	1.3	1.3	-
		43	-	-	2.7	14.7	18.7	22.7	29.3	8.0	4.0	-
South of Nitinat Canyon	He 3A	34	-	-	14.1	37.2	15.4	19.2	6.4	3.8	1.3	2.6
		35	-	6.1	51.2	25.6	12.2	2.4	2.4	-	-	-
		average	-	3.05	32.65	31.40	13.80	10.80	4.40	1.90	0.65	1.36
Finger Bank - Southeast Corner	He 4	3	-	-	48.1	37.0	4.9	4.9	3.7	1.2	-	-
		5	-	-	8.2	50.7	26.0	11.0	4.1	-	-	-
		26	-	-	21.6	42.0	26.1	3.4	4.5	1.1	1.1	-
		40	-	-	23.0	33.8	23.0	6.8	12.2	1.4	-	-
		42	-	-	6.8	25.7	37.8	10.8	12.2	2.7	2.7	1.4
Swiftsure Bank	He 10	average	-	-	21.54	37.84	23.56	7.38	7.34	1.28	0.76	0.28
		1	-	-	7.4	33.3	40.7	12.3	3.7	2.5	-	-
		2	-	38.5	32.3	16.9	2.7	3.1	-	1.5	-	-
		47	-	10.4	41.7	14.6	16.7	14.6	-	-	2.1	-
		48	-	-	33.3	34.7	14.7	6.7	5.3	4.0	1.3	-
		49	-	-	35.6	39.7	15.1	6.8	1.4	1.4	-	-
Rockfish Concentrations	Ro	50	-	-	49.3	28.4	13.6	1.2	6.2	1.2	-	-
		average	-	8.15	33.27	27.93	18.08	6.39	2.77	1.77	0.57	-
		18	-	7.7	59.6	25.0	3.8	1.9	-	-	1.9	-
	Ro	21	-	-	18.7	31.3	17.2	9.4	10.9	7.8	1.6	3.1
		average	-	3.85	39.15	28.15	10.5	5.65	5.45	3.90	1.75	1.55

Table 4. Biomass (metric tons)^a by species and fish concentration on the West Coast of Vancouver Island, September 8-25, 1981.

Location	Conc. no.	Total	Biomass (t)								
			Herring	Eulachon	Hake	Pollock	Dogfish	Yellowtail rockfish	Redstripe rockfish	Other rockfish	Other
Northern La Pérouse Bank	He 1	10	8	-	+	-	+	1	1	+	-
Father Charles/ Loudoun Canyons	He 2	13,200	10,200	-	13	-	13	930	1,400	190	454
Barkley/Nitinat Canyons	He 3	37,600	19,100	-	38	-	16,700	190	1,200	190	182
South of Nitinat Canyon	He 3A	7,100	5,100	-	540	-	1,200	170	50	-	40
Finger Bank/SE Corner	He 4	8,800	7,600	-	-	-	1,200	9	-	-	-
Off Amphitrite Pt.	He 5	28	28	-	-	-	-	-	-	-	-
SW Corner/Cabbage Patch	He 6	1,200	1,200	-	-	-	-	-	-	-	-
SW Corner	He 7	28	28	-	-	-	-	-	-	-	-
Steep Edge	He 8	140	140	-	-	-	-	-	-	-	-
Cape Beal Spit	He 9	6	6	-	-	-	-	-	-	-	-
Swiftsure Bank	He 10	18,200	16,900	-	-	-	1,200	36	-	-	64
Cape Flattery Spit	He 19	9	6	-	1	-	1	+	+	-	1
Firing Range	Ha 12	18,000	+	18	14,200	3,000	680	-	-	-	102
Barkley Basin	Ha 13	11,800	+	12	9,300	2,000	450	-	-	-	38
Eastern Prairies	Ha 14	18,700	+	19	9,700	5,100	240	2,300	860	300	181
Eastern Prairies	Ha 14A	3,000	+	3	1,500	810	39	370	140	48	90
Juan de Fuca Trench	Ha 15	7,000	+	7	3,600	1,900	90	860	320	110	113

Table 4 (cont'd).

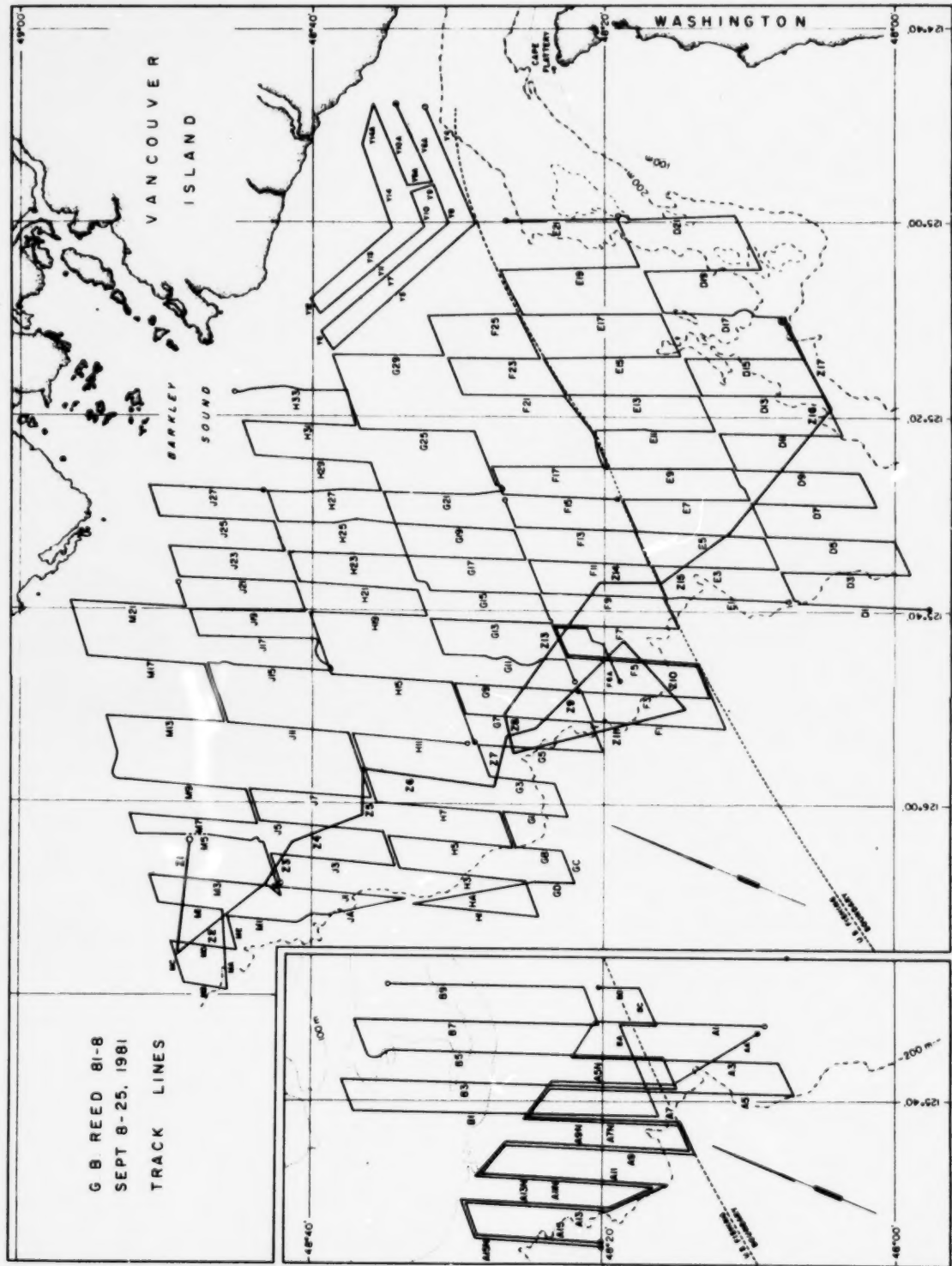
Location	Conc. no.	Total	Biomass (t)								Other
			Herring	Eulachon	Hake	Pollock	Dogfish	Yellowtail rockfish	Redstripe rockfish	Other rockfish	
Off Swiftsure Bank	Ha 16	1,400	+	1	730	390	18	180	66	23	-
Cape Beale Spit	Ro 15	170	-	-	-	-	-	-	-	170	-
Central Prairies	Ro 16	2,500	320	-	-	-	-	1,100	1,000	27	53
South Prairies	Ro 17	1,600	200	-	-	-	-	710	640	18	32
C. Flattery Spit	Ro 18	6,600	860	-	-	-	-	3,000	2,700	72	-
Off C. Beale	Ro 21	2,900	+	-	-	-	-	-	-	2,900	-
Juan de Fuca Trench	Ro 22	31	4	-	-	-	-	14	13	+	-
Total		160,022	61,700	59	39,622	13,200	21,831	9,870	8,389	4,048	1,350

^a Biomasses greater than 1000 t are rounded to the nearest 100 t, and from 100 to 1000 t are rounded the nearest 10 t.

Table 5. Biomass (metric tons)^a by species in the original and repeat surveys, September, 1981.

	Total	Herring	Bulachon	Hake	Pollock	Dogfish	Yellowtail rockfish	Redstripe rockfish	Other rockfish	Other
1. Finger Bank/Southeast Corner concentration - North of diagonal										
Original	11,000	9,400	-	-	-	1,400	11	-	-	189
Repeat	42,200	36,300	-	-	-	5,400	42	-	-	458
2. Outer shelf concentration - south of diagonal, north of U.S./Can. boundary										
Original	58,900	29,800	-	59	-	26,100	300	1,800	300	541
Repeat	30,100	15,200	-	30	-	13,300	150	900	160	360
3. Outer shelf concentration - south of U.S./Can. boundary										
Original	8,500	6,100	-	640	-	1,400	200	59	-	101
Repeat	13,400	9,700	-	1,000	-	2,300	320	120	-	-

^aBiomass greater than 1000 t are rounded to the nearest 100 t, and from 100 to 1000 t are rounded to the nearest 10 t.



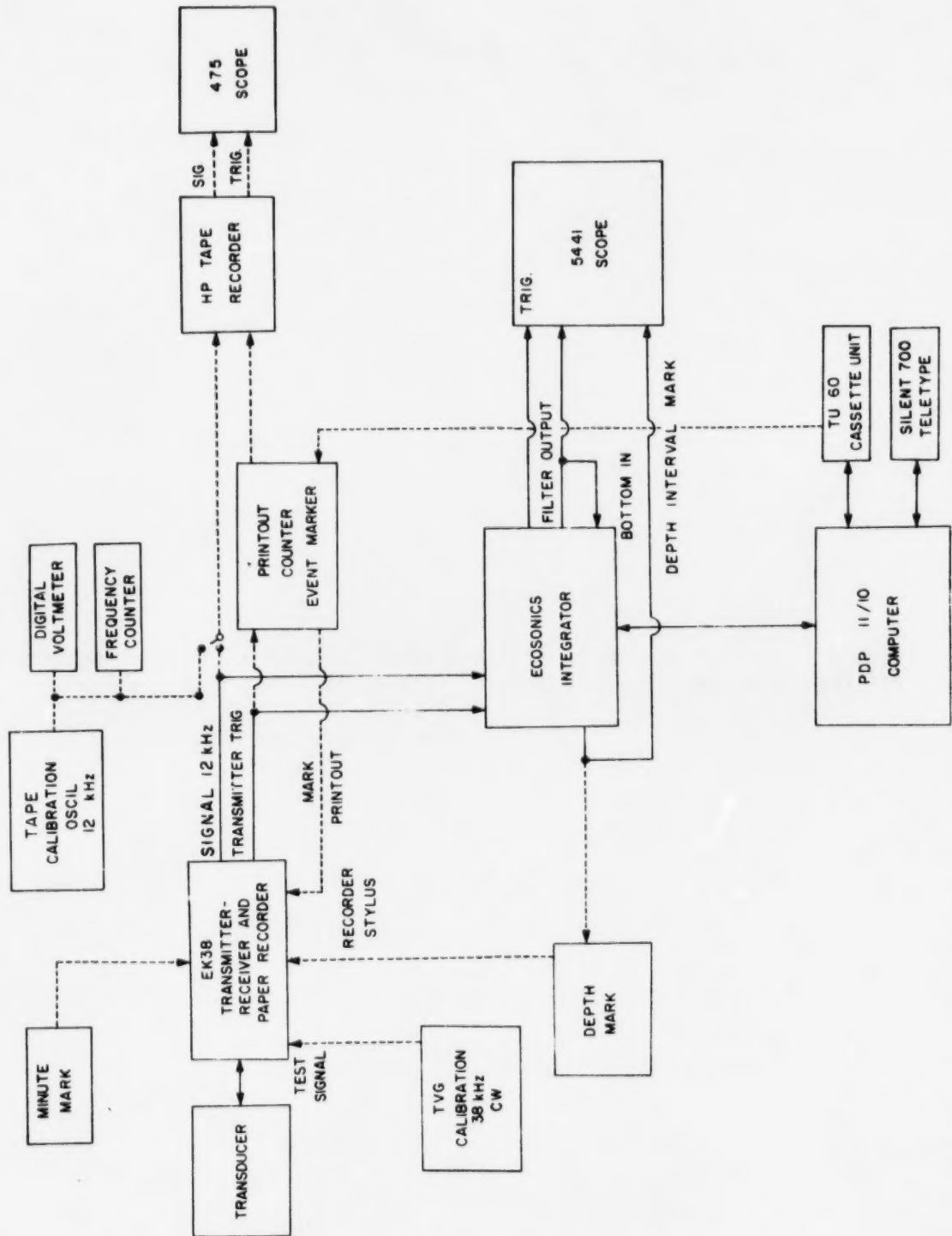


Fig 2. Block diagram of the echo integration system, and auxiliary equipment used on the G.B. REED, September 8-25, 1981.

Fig. 3. Chart of the relative fish density (density x target strength per kg) off the southwest coast of Vancouver Island, September 8-25, 1981.

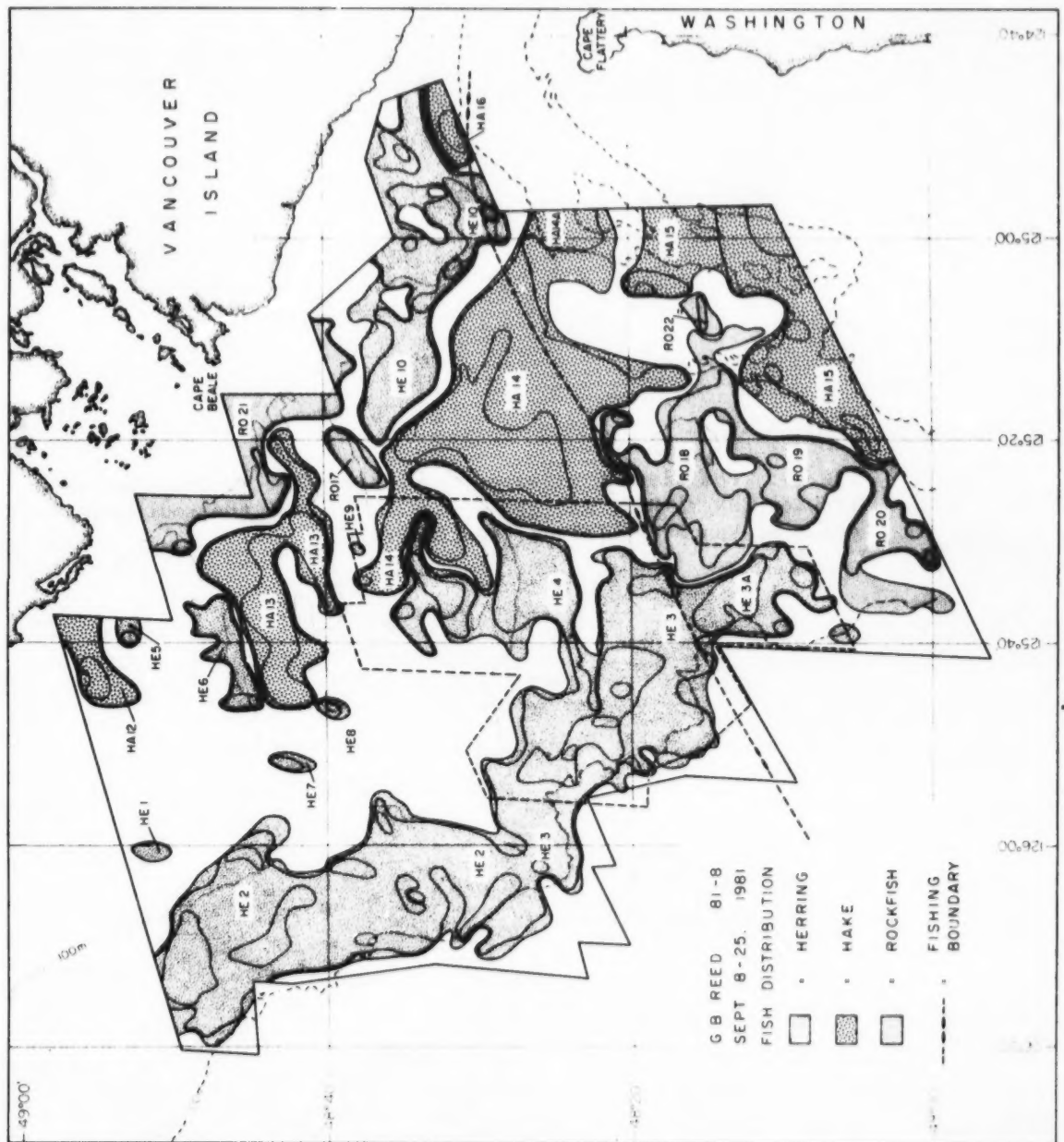
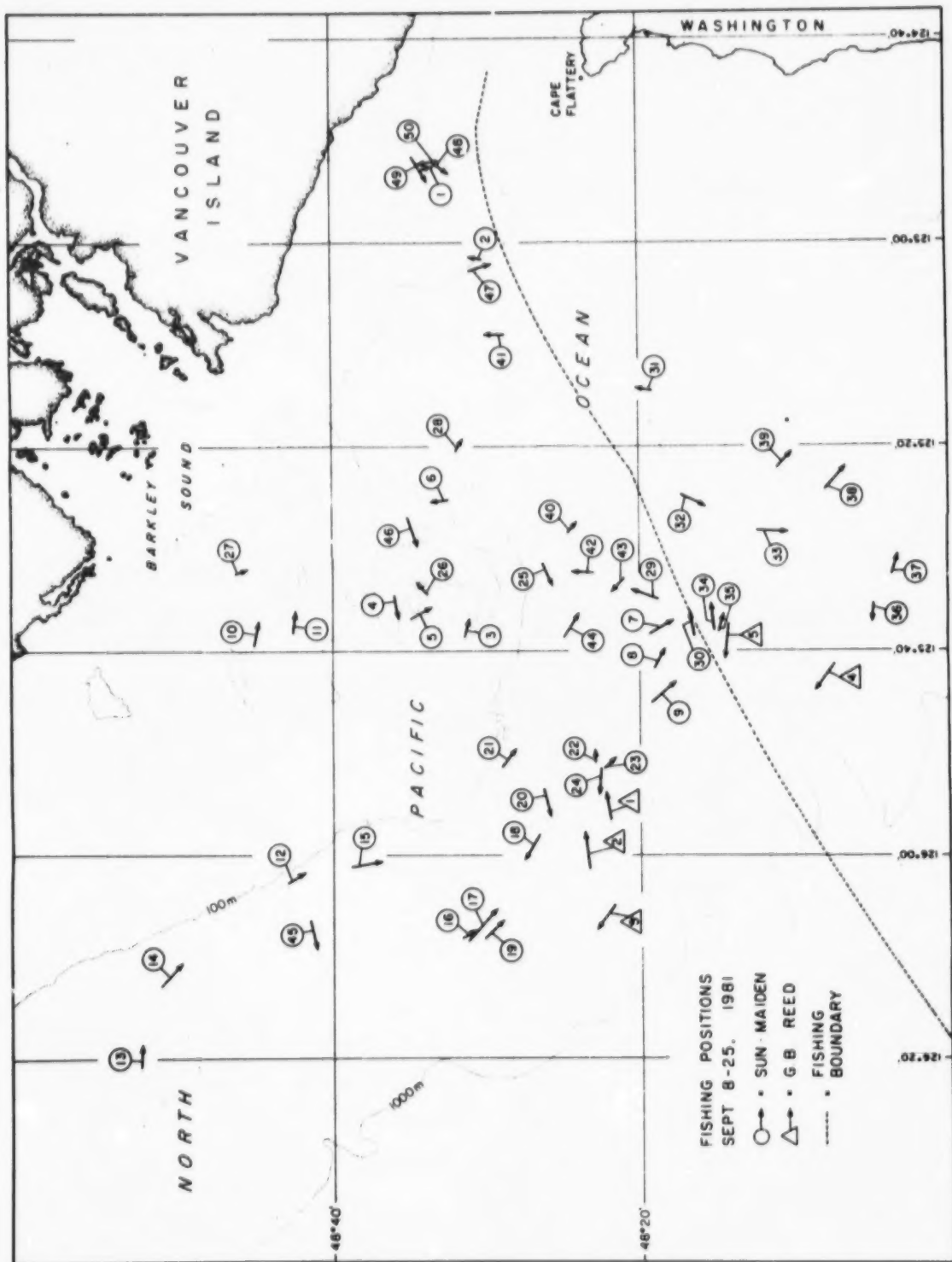


Fig. 4. Position of midwater trawl tows made by the chartered trawler SUN MAIDEN, and by the G.B. REED, off the southwest coast of Vancouver Island, September 8-25, 1981.



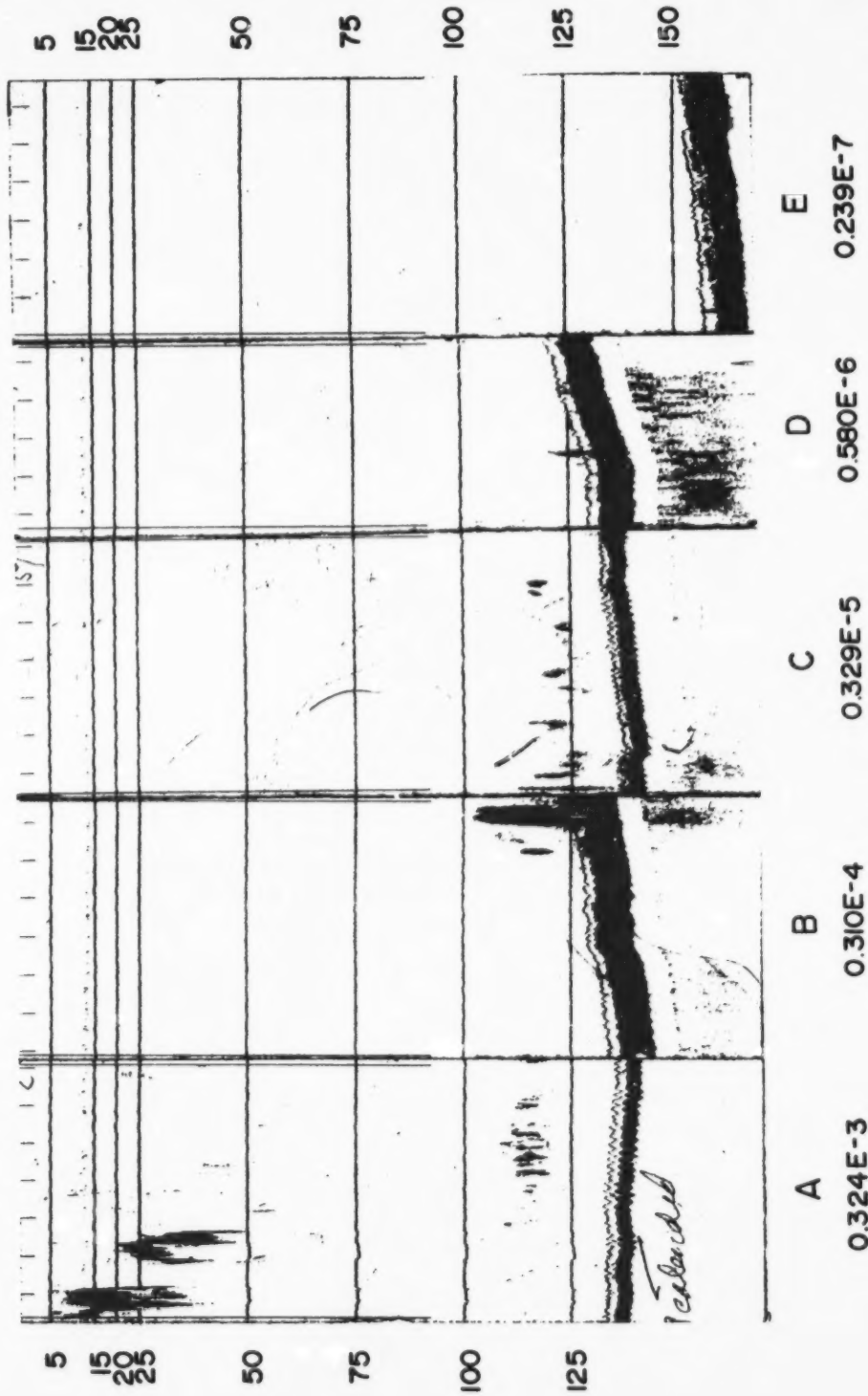


Fig. 5. Examples of herring schools of various relative densities off the southwest coast of Vancouver Island, September 8-25, 1981. The vertical scale is in meters.



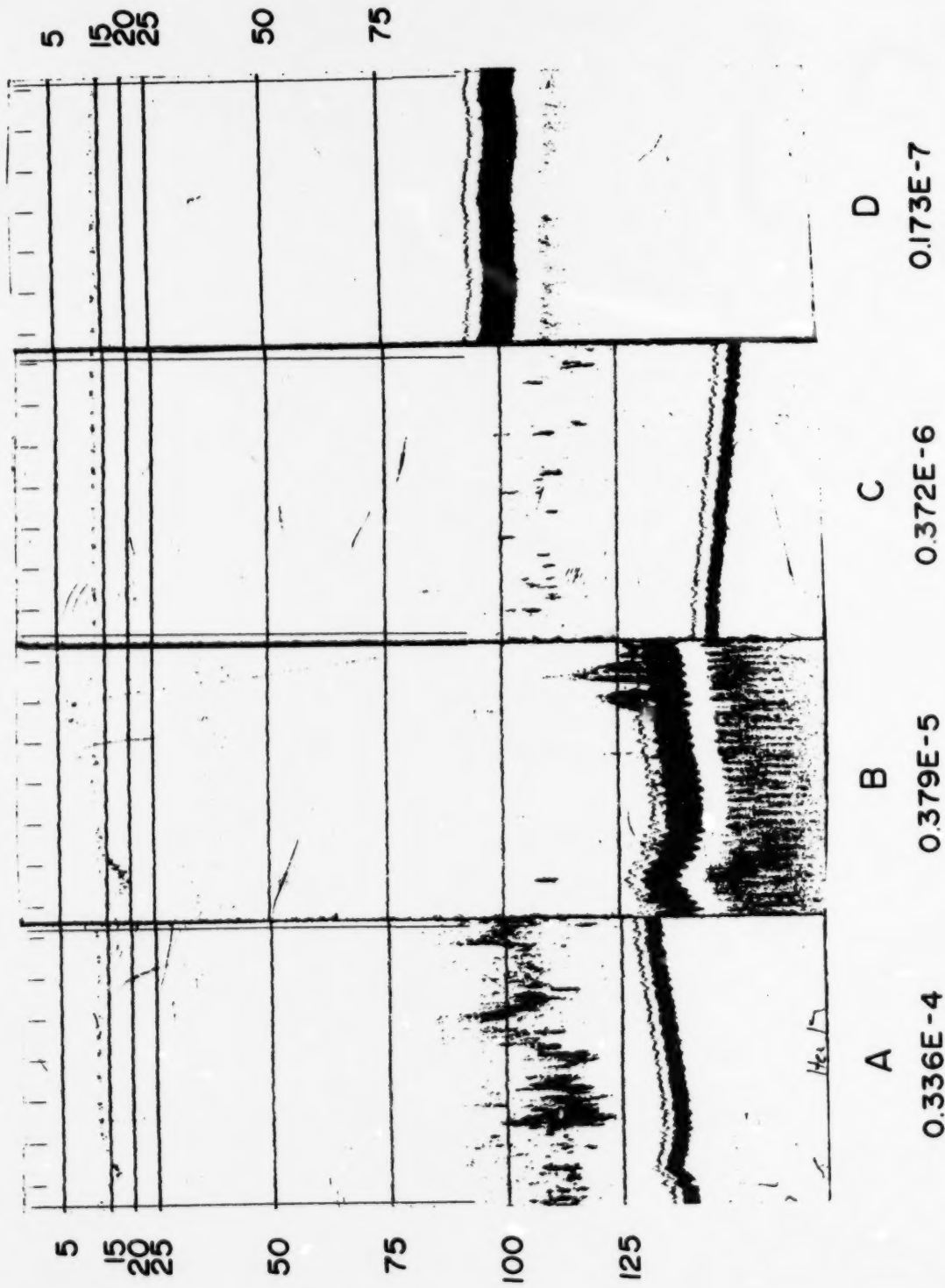


Fig. 6. Examples of hake schools of various relative densities off the southwest coast of Vancouver Island, September 8-25, 1981. The vertical scale is in meters.



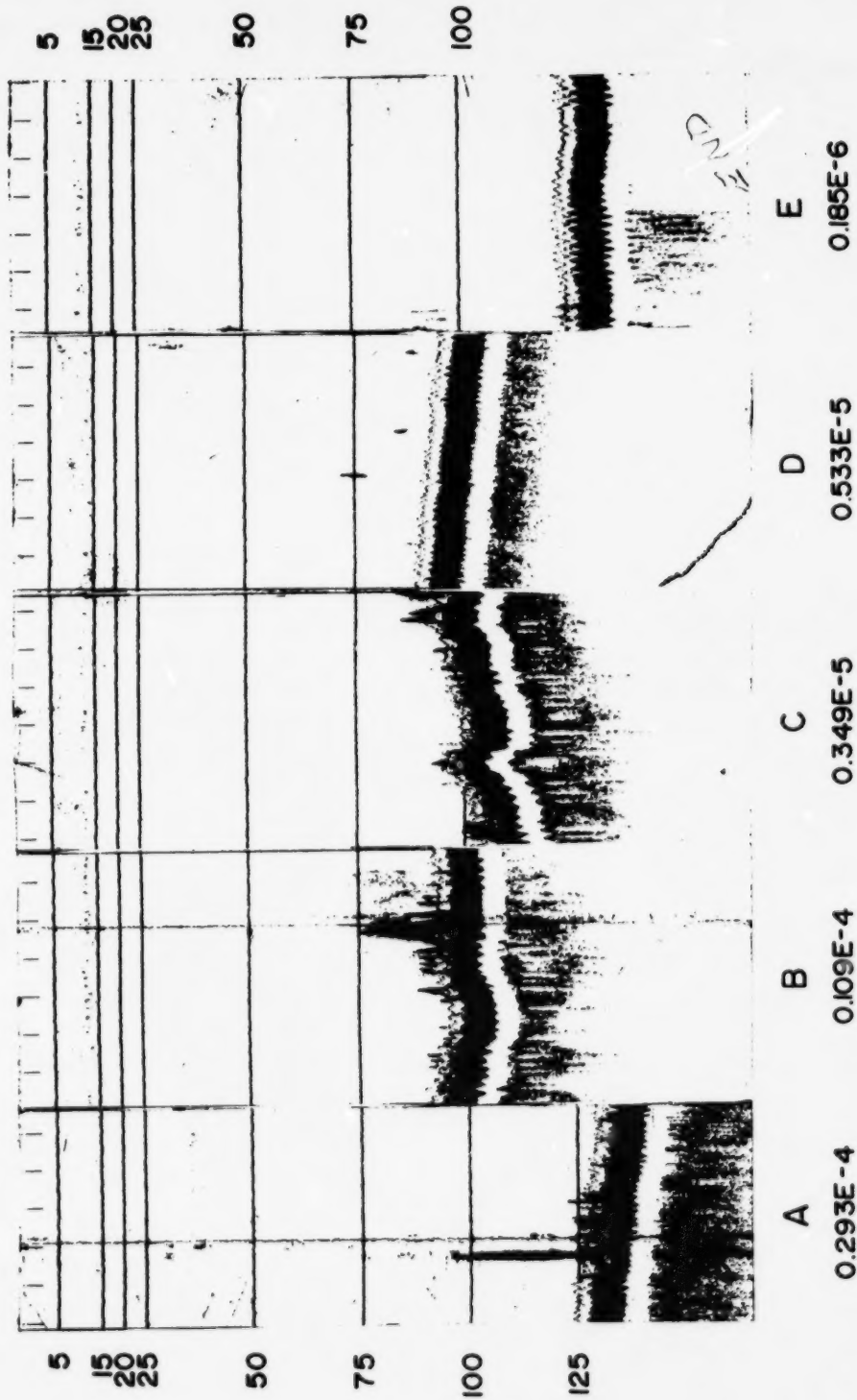
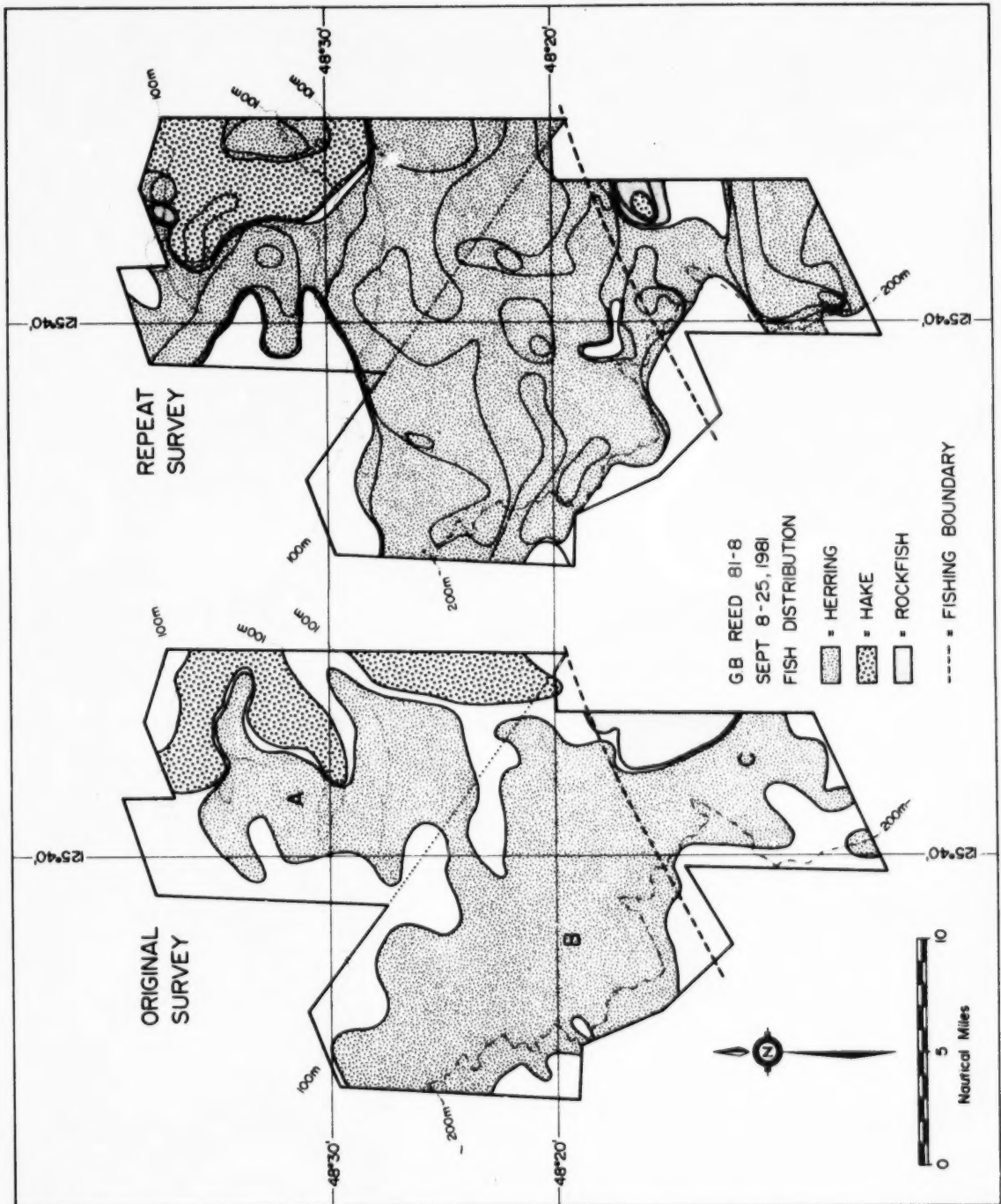


Fig. 7. Examples of rockfish schools of various relative densities off the southwest coast of Vancouver Island, September 8-25, 1981. The vertical scale is in meters.

Fig. 8. Charts of relative fish density in the area surveyed on the original and repeated survey in cruise GBR81-8, September 8, 1981. Note: The dashed line is the U.S./Canadian fishing boundary; the dotted line is a survey block boundary.





APPENDIX 1 - HYDROACOUSTIC SYSTEM AND CONSTANTS

A. HYDROACOUSTIC SYSTEM

The hydroacoustic system used on the G.B. REED from September 8-25, 1981 was the same as that used on the cruises the preceding year from September, 1980 to March, 1981.

It consisted of:

- a) Biosonics transmitter-receiver, model 101, 38 KHz, 1000 W.
- b) Simrad ceramic transducer, 38 KHz, with 15 x 30 cm radiating face giving 13° x 7° beam between 3 dB points. Serial No. S4318.
- c) Simrad EK38-S dry paper echosounder recorder.
- d) Ecosonics echointegrator.
- e) Digital Equipment Corporation PDP 11/10 computer.
- f) Digital Equipment Corporation TU60 cassette unit.
- g) Texas Instrument Silent 700 computer terminal
- h) Hewlett-Packard 4-channel instrumental tape recorder model 3960 F.
- i) Tektronix storage oscilloscope model 5403.
- j) Fathom Oceanology towed body, model 3-397-10.
- k) Armoured towing cable for above, 95 m, 3 twisted shielded pairs of conductors.
- l) Associated custom-built units to produce calibration signals, timing signals to tape and chart recorder, and print-out counter.

B. SYSTEMS CONSTANTS

The model for the hydroacoustic biomass estimation was the same as used by Taylor and Kieser (1980, 1981), with the addition of an extra term to account for losses produced by the shell of the towed body.

$$\bar{I}_{mn} = TL + VR + RG + SL + BW + KTVG + RI00 + \psi + 10 \log \frac{c_T}{2} + \bar{TS}_{mn} + 10 \log \bar{\rho}_{mn}$$

The constants used on this cruise are given below:

1. Source Level (TL)

$$TL = 222.8 \text{ dB } \mu\text{Pa}, 1 \text{ m}$$

2. Voltage Response (VR)

$$VR = -99.1 \text{ dB V/}\mu\text{Pa with TVG at 100 m}$$

3. Receiver Gain (RG)

$$RG = -12.00 \text{ dB}$$

4. Shell Loss (SL)

$$SL = -1.1 \text{ dB}$$

5. Bandwidth Factor (BW)

$$10 \log \frac{I_C}{I_S} = -0.96 \text{ dB}$$

The intensities I_C and I_S are obtained by integrating a receiver calibration pulse and a 0.6 ms square pulse respectively. Both signals must be of equal maximum height and identical integrator settings are used.

6. TVG correction factor: 0 dB.

7. Spreading and absorptive loss at reference depth (R100)

$$R100 = -(2 \alpha 100 + 20 \log 100) = -41.98 \text{ dB.}$$

8. Beam Factor (ψ)

$$= -17.55 \text{ dB}$$

9. Depth Slice

$$10 \log \frac{C_T}{2} = 10 \log \frac{1500}{2} \times 0.0006 = -3.47 \text{ dB}$$

With these factors the above equation is:

$$\bar{I}_{mn} = 222.8 - 99.1 - 12.00 - 1.1 - 9.6 + 0 - 41.98 - 17.55 - 3.47 + \bar{TS}_{mn} + 10 \log \bar{\rho}_{mn}$$

$$\bar{I}_{mn} = 46.64 + \bar{TS}_{mn} + 10 \log \bar{\rho}_{mn}$$

C. TVG CORRECTION FACTOR

The Biosonics echosounder has proved to have an accurate TVG circuit. Consequently no secondary TVG corrections are required.

D. TARGET STRENGTH VALUES

Our equipment cannot be used to measure target strength *in situ*, consequently the values used are calculated from a relationship derived by R. Kieser from published values (Taylor and Kieser 1982).

For fish with a swim bladder the relationship is:

$$TS/kg = -7.20 \log L - 36.60$$

For fish without swim bladder it is:

$$TS/kg = -8.44 \log L - 48.54$$

In the above equations fish length (L) is in metres. These equations have been used to obtain for each major species the target strength values in the table below to convert acoustic backscattering measurements to biomass estimates.

Species	Modal length (m)	% at mode	Average length (m)	Calculated TS	Rounded TS
Herring	0.082	2	-	-29.0	-29.0
	0.142	17	-	-30.7	-31.0
	0.190	68	-	-31.6	-32.0
	0.242	3	-	-32.6	-33.0
	Weighted average		-	-31.5	-32.0
Hake	-	-	0.556	-35.0	-35.0
Pollock	-	-	0.387	-33.8	-34.0
Yellowtail rockfish	-	-	0.436	-34.2	-34.0
Redstripe rockfish	-	-	0.321	-33.2	-33.0
Widow rockfish	-	-	0.351	-33.5	-34.0
Dogfish	-	-	0.731	-47.39	-47.0